CURRENT STATUS, PERFORMANCE AND PLANS FOR THE NASA AIRBORNE VISIBLE AND INFRARED IMAGING SPECTROMETER (AVIRIS)*

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ABSTRACT

The status of the Airborne Visible and Infrared Imaging Spectrometer (AVIRIS) is reported at the beginning of the current flight season. Sensor performance based on laboratory measurements and trend data as well as a review of end of 1995 season performance is given as a measure of expected performance during the 1996 flight season which began in March of 1996. Recent improvements to the sensor's internal calibration source and measurements of instrument parameters arc described. The effects of these enhancements on the reported data are also discussed along with an update on flight schedules and plans for 1996 flight operations.

1.0 INTRODUCTION

The Airborne Visible and Infrared Imaging Spectrometer (AVIRIS), was first flown in 1987 under the support of the NASA Mission Planet Earth Program. Since attaining operational status in the 1989/1990 season, the sensor has supported over 200 launches aboard NASA ER-2 aircraft to acquire imaging spectrometry data for scientific and engineering evaluations spanning a wide variety of scientific disciplines and applications. As will be discussed below, the sensitivity and calibration of the AVIRIS data has improved significantly since its original flights with some of the most dramatic improvements being made for the 1995 flight season. Continuing incremental improvements for 1996 will again increase the utility of AVIRIS data to scientific, commercial and government users alike. The primary objectives of the AVIRIS program continue to be to provide high quality imaging spectrometry data sets to enable the quantitative characterization of the Earth's surface and atmosphere from calibrated spectra acquired as images. Figure 1 illustrates the concept of imaging spectrometry as employed by AVIRIS.

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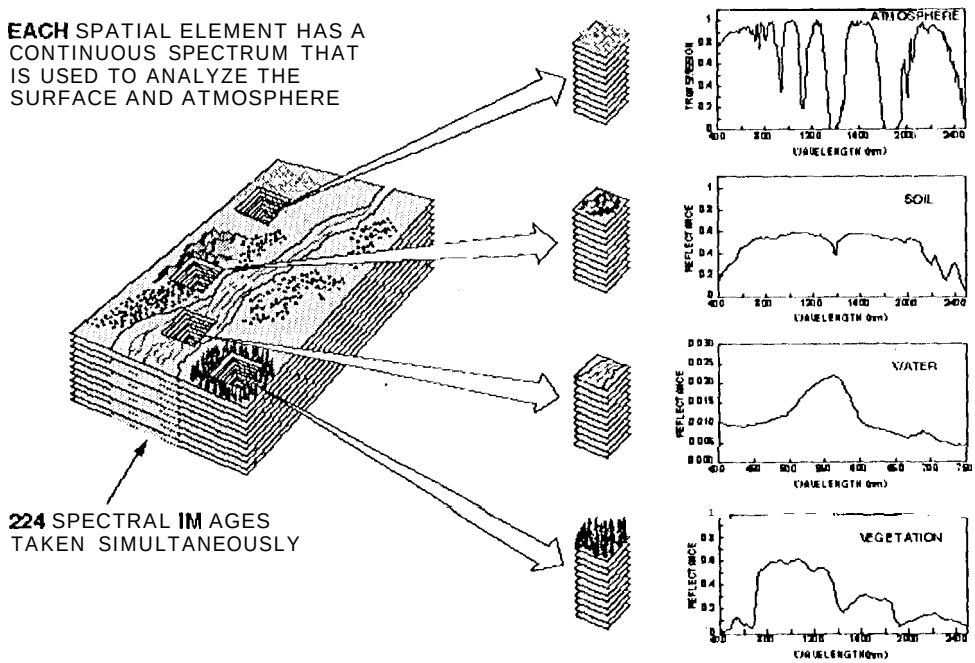

Figure 1. AVIRIS Measurement Approach

2.0 SENSOR CHARACTERISTICS

AVIRIS is a whiskbroom imaging spectrometer operating in the solar reflected visible, near infrared and short wave infrared regions of the spectrum. It is configured to fly aboard the NASA ER-2 aircraft at a nominal altitude of 20 km and collects an 11 km wide swath at a 20 m ground sample distance (GSD). Spectral data are simultaneously acquired in four spectrometers and focal planes covering 224 spectral bands from 380 to 2500 nm. Spectrometer data are digitized to 12 bits and stored on a high density digital tape. Flight missions are typically 6.5 hours in length at a nominal airspeed of 734 km/hr giving a range to target of over 2100 km from the launch point while still allowing ample time for collection of data at the target site. The sensor data recorder can acquire and store 10 gigabytes or approximately 8000 km^2 on a high density tape. Figure 2 shows the mechanical configuration of the AVIRIS sensor. Additional sensor and data characteristics are given in Table 1.

AVIRIS Data Characteristics	
SPECTRAL	
Wavelength Range	380 to 2500 nm
Sampling	≤ 10 nm
Spectral Response (FWHM)	10 nm nominal
Calibration	0.1 nm
RADIOMETRIC	
Radiometric Range	O to maximum lambertian radiance
Sampling	12 bits -1 bit noise rms
Absolute Calibration	≥ **96%**
Intra Flight Stability	≥ 98%
GEOMETRIC	
Field of View	30 degrees (11 km)
Sampling	**0.9** mrad (17 mrad)
Instantaneous FOV	1.0 mrad (20 m)
Calibration	≤ 0.1 mrad
Flight Line Length	10 * 80 km
AVIRIS Instrumentation Characteristics	
SENSOR	
Sensor Type	Whiskbroom Scanner(121]7)
Spectral Dispersion	Four Grating Spectrometers
Detection	224 detectors (32,64,64,64) Si, InSb
Digitization	12 bits
Data Rate	20.4 mbits/see
Spectrum Acquisition Rate	7300 spectra/sec
Data Capacity	10 gigabytes (≥ 8000 km^2)
Weight	330 kg for ER-2 Aircraft
Power	-2 kW (400 Hz, 100 v, **28** VDC)
Launches	> 30/year
DATA FACILITY (nominal)	
Performance Monitoring/Data QA	≤ **48** hours from acquisition
Archiving	< 2 weeks from acquisition
Quicklook	< 2 weeks, published on WWW
Calibrated Data Product Distribution	≤ 3 weeks from request
PLATFORM	
Aircraft	NASA ER-2
Altitude	20 km
Speed	734 km/hr (nominal)
Range	~ 2100 km
Flight Duration	6.5 hrs (nominal)
Launch Sites	Domestic and Foreign

Table 1. AVIRIS System Characteristics

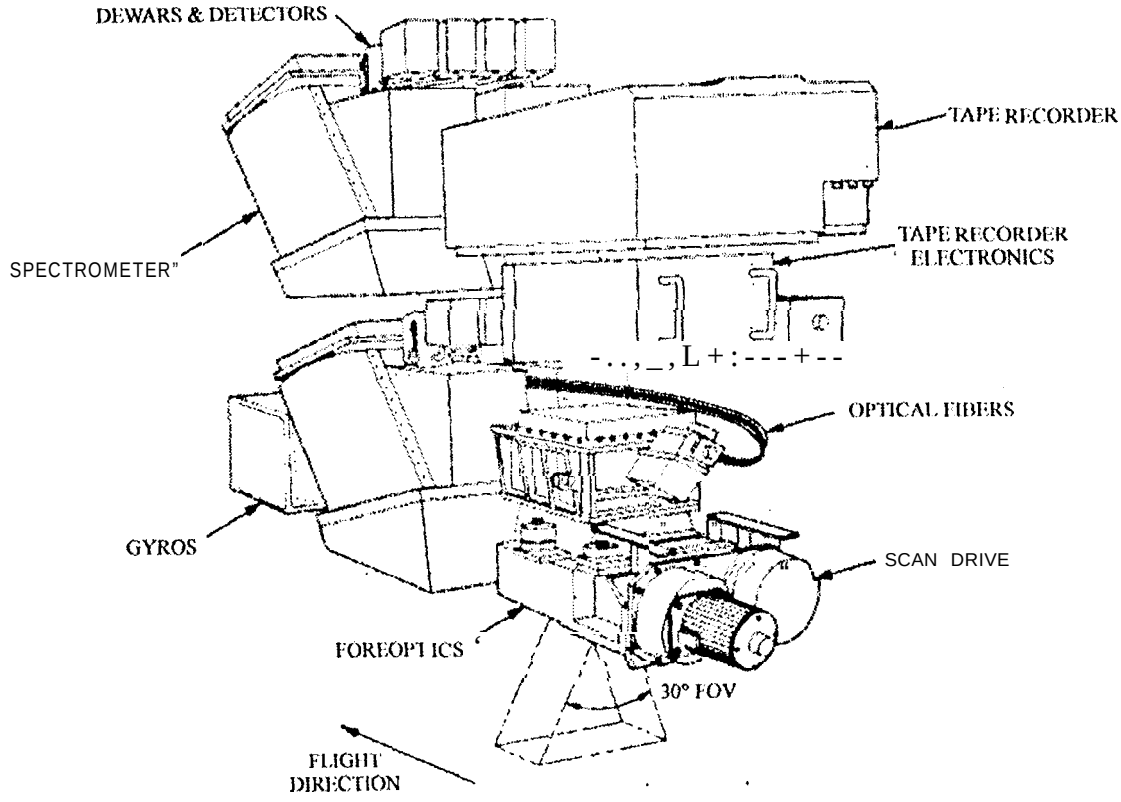

Figure 2. AVIRIS Sensor Layout

3.0 SENSOR PERFORMANCE

Careful attention is paid to the calibration and stability of the AVIRIS sensor in order to assure the delivery of reliably high quality data to the user. Laboratory calibrations to verify spectral, spatial and radiometric performance are conducted approximately three times per flight season to monitor the per formancc and stability of the instrument. (Chrien et al., 1996) In-flight calibration validation experiments are also conducted several times per year to assure that the performance of the sensor in the actual flight environment (- 4psi and 10 C average temperat ure) matches the performance in the laboratory. During these flight validation experiments, the radiance at the AVIRIS sensor is predicted using ground truth measurements of solar irradiancce, surface reflectance and atmospheric conditions to constrain a MODTRAN 3 radiative transfer code. The AVIRIS measured radiance is then computed using the laboratory calibration data and is compared to the independent path predicted radiance from MODTRAN 3. Figure 3 show the results of the inflight calibration experiment performed at the beginning of the 1995 season (Green et al., 1996). Agreement between the AVIRIS measured radiance and the predicted radiance at the 96.5% level is reported for this experiment with the residual

uncertainties being attributable to residuals and uncertainties in the MODTRAN code, ground truth measurements, and the laboratory calibration standards as well as uncertainties in the AVIRIS sensor.

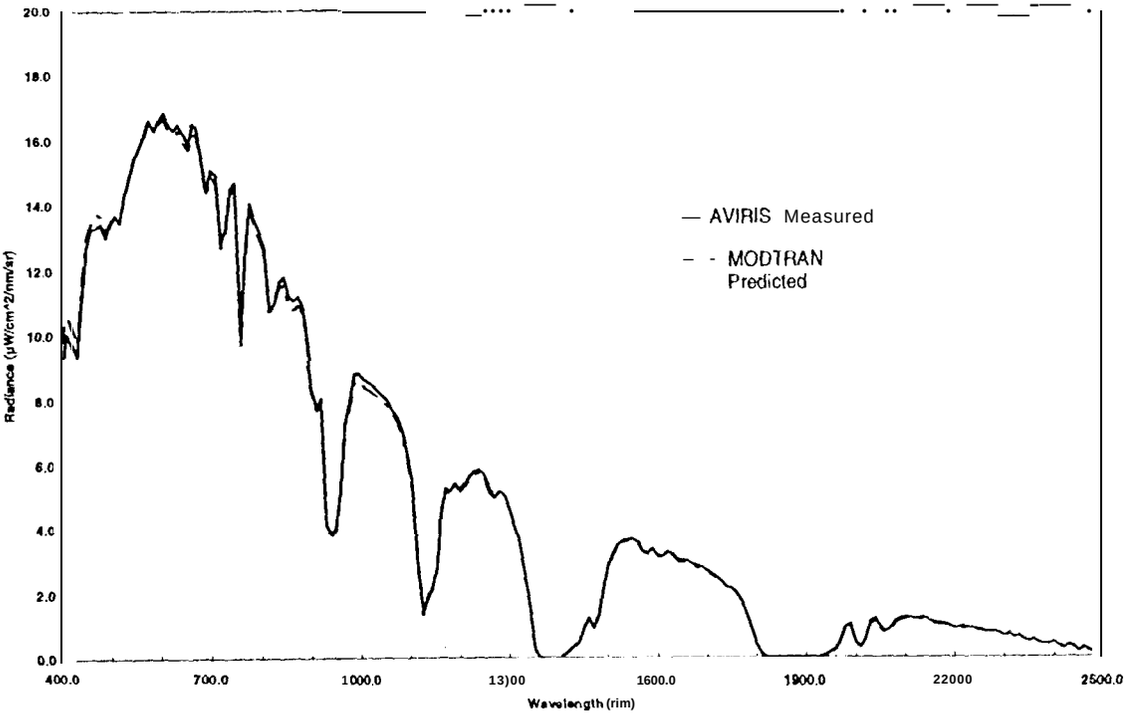

Figure 3. Comparison of MODTRAN3 predicted and AVIRIS measured upwelling spectral radiance for the calibration site at Ivanpah Playa, CA

The other primary metric for AVIRIS performance is the signal to noise ratio, SNR is reported for a reference radiance from a 50% albedo target at sea level illuminated at a 23.5 degree solar zenith angle through a mid-summer model atmosphere. AVIRIS performance has been reported against this reference radiance level since its first flights in 1987 and has been continually monitored each flight year. Performance of the sensor during the 1995 flight season (April through November 1995) is shown in Figure 4. The significant increase in performance from 1994 was due primarily to the introduction of new focal plane detectors and readout multiplexer for the 1995 season.

AVIRIS performance for 1996 is predicted to be equal to 1995 performance. As of the submission date of the paper, the sensor has just been delivered for the 1996 flight season. Laboratory calibration and trend data acquired just prior to delivery indicate performance very nearly identical to 1995 levels. An in-flight calibration/validation

experiment to measure 1996 calibration and signal to noise performance will be conducted at the earliest opportunity once flight operations have begun.

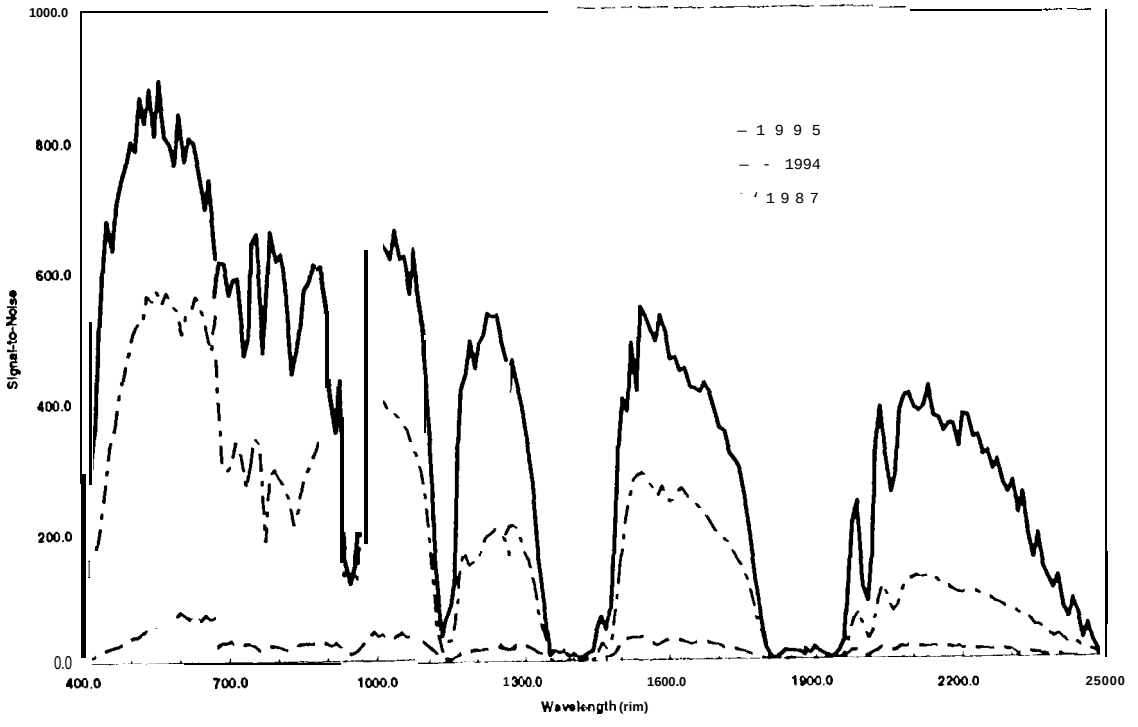

Figure **4.** AVIRIS Signal to noise ratio (SNR) for the 1995 in-flight calibration experiment conducted 5 May 1995 at Ivanpah Playa, CA.

4.0 CHANGES FOR 1996 SENSOR FLIGHT SEASON

In addition to the changes made to the sensor in 1995 to significantly increase basic performance (new focal planes/multiplexers, 12 bit digitization, etc.) several other changes have been implemented to increase the utility and quality of the data set for the 1996 season.

In 1995, the on board reference source was modified to include a closed loop controller driven by the signal from a stable silicon photodiode measuring the source output. During **1995,** the output of the on board reference was included in the reported cal file data delivered with the instrument data but was not used to modify the reported radiance from AVIRIS. After monitoring the stability and performance of the new detector based source controller throughout the 1995 flight season, the on board reference will, in 1996, be used as a true on board calibrator (OBC) for AVIRIS. Calibrated Radiance data products beginning in 1996 will use the output of the OBC as

reported by the AVIRIS detectors to correct for residual short-term instabilities in the instrument outputs.

In addition to the incorporation of the OBC data in the computation of the calibrated radiance, AVIRIS data delivered in 1996 will include 64 samples of dark current for each detector measured at the end of each scan line.

A modification to the operational infrastructure for AVIRIS will include more extensive usc to the World Wide Web to communicate status and plans to the users of AVIRIS. Beginning with the first flights of AVIRIS in the 1996 season, complete flight planning and history data will be available on the AVIRIS web site, (ftp://ophelia.jpl.nasa.gov/README.htm/) This data base will be updated daily during flight operations periods and will include many of the items previously unavailable except through individual inquiry by phone or fax.

5.01996 FLIGHT SEASON PLANS

AVIRIS was delivered to NASA Ames Research Center, Moffett Field for the start of the 1996 flight season in early March and successfully conducted an initial checkout flight on 1 March. The flight season includes operations from Moffett, Wallops Island, VA, Houston, TX, and Seattle WA continuing through October of 1996. Current plans include acquisition of data for approximately 30 investigators and over 200 flight lines. Additional reimbursable and cooperative flights may be added through the flight season. I'able 2 shows the current operational periods and locations for AVIRIS during the year.

Deployment Site	Start Date	End Date
Moffett Field, CA	March 01	March 12
Houston, TX	March 14	March 27
Moffett Field, CA	April 01	June 17
Wallops Island, VA	June 19	July 29
Spokane, WA	July 31	August 19
Moffett Field, CA	August 2.1	October 30

Table 2.1996 AVIRIS Operational Schedule

6.0 CONCLUSION

AVIRIS continues to operate reliably to provide high performance and well calibrated data sets to a broad user community encompassing scientific researchers, commercial users, and users from other government and public entities. As AVIRIS has

continually improved over the years, the applications to which the data are put also expand and improve. With the continued support of the NASA Mission to Planet Earth Office, AVIRIS will continue to provide high quality data well into the next decade.

7.0 AKNOW1 .EDGEMENTS

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8.0 REFERENCES

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R. O. Green, et al., "In-Flight Calibration and Validation of the Airborne Visible/J nfrared Imaging Spectrometer (AVI IllS)." In *Summaries of the Sixth Annual JPL Airborne Earth Science Workshop, Vol. 1, A VIRIS,* ed, R.O. Green, Pasadena CA, 4-6 March 1996. (In press).